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Interpretation of the Great Plains Polygonal Fault
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(i) Summary.
Fine-grained Cretaceous sediments of the Western Interior Seaway of North America host a previously unreported polygonal fault system (PFS). The Great Plains PFS (GPPFS) is an expansive network of fractures and faults that could be the Earth’s largest PFS. Interpretation of seismic data in the Pierre Shale depositional area has identified faulted strata with a polygonal planform geometry of aggregated fault traces indicative of PFS.

4) After deposition, the subaqueous muds underwent normal faulting. Cartwright (1994) and others have researched this topic; the cause of the faulting is still being discussed. The work here is focused on the GPPFS presence (the cause is work in progress).

A 3-D seismic dataset from Alida, Saskatchewan provides some insight into fault timing and geometry for the GPPFS. Here, faulting in the GPPFS appears to have occurred in two stages. The lower tier is Coniacian to Campanian, has a base at ~25 m ASL, with larger faults having average throws of ~10-15 m and a fault density of ~10 faults/mile². This tier forms a series of grabens at the top, suggesting Middle Campanian local or regional extension. The upper PFS tier (Upper Campanian) has similar fault throws and areal densities, but the faults are longer in length and the predominant strike azimuth changes. Also, the upper PFS tier has developed into tilted fault blocks that increase in offset up to the base of the Tertiary at 500 m ASL, ~100 m below surface. The data presented here are representative of seismic data, surface geology, landslides, and well control that could be indicating that the GPPFS could be >2,000,000 Km² in area. The geotechnical engineering implications are numerous where the PFS is at outcrop or near outcrop.

6) Let’s examine the results of this phenomenon at Alida, Saskatchewan. The Alida pool is ~830 miles northeast of Denver. It has a 3-D seismic volume, as outlined in red:

7) The Turonian 2WS seismic reflection images no detected faulting.

8) West to east seismic line from ~250 – 600 m depth:

9) Summary so far:
- The Turonian 2WS two way traveltime map shows a southwest to northeast structural rise consistent with regional dip without faulting.
- The west to east seismic line images faults above the Turonian 2WS.
- Consider the Coniacian Govenlock Two Way Traveltime map, the next shallower reflection above the Turonian 2WS.


11) Coniacian Govenlock to 2WS isochron (time difference).

1) Start ~ 100 MA (Cenomanian) and deposit siliciclastics in the Western Interior Seaway.

2) From the Campanian to the Maastrichtian, siliciclastics were deposited over ~2.6 million Km², up to 2,400 m thick at Boulder, Colorado (Scott and Cobban, 1965). This is the Pierre Shale.

3) Use Age names over the large area:

4) After deposition, the subaqueous muds underwent normal faulting. Cartwright (1994) and others have researched this topic; the cause of the faulting is still being discussed. The work here is focused on the GPPFS presence (the cause is work in progress).

5) Let’s examine the results of this phenomenon at Alida, Saskatchewan. The Alida pool is ~830 miles northeast of Denver. It has a 3-D seismic volume, as outlined in red:

6) At Alida, the Pierre shale is ~400 m thick.

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9) Summary so far:
- The Turonian 2WS two way traveltime map shows a southwest to northeast structural rise consistent with regional dip without faulting.
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- From Blakey, 2014

- This entire area could host a polygonal fault system. (from Robert and Kirschbaum, 1995)
12) Santonian to Coniacian Govektoll Isochron (time difference).

The map and seismic line show the Santonian reflection. Numerous grabens occur after Campanian Lea Park but before the Campanian Outlook reflection. This is confirmed by well control.

13) a, b, c Three maps show how we can compute a residual map for the Campanian Lea Park to estimate the graben geometries.

14) Another way to characterize the faulting is to display horizon gradient maps. Observe the difference between the Campanian Lea Park gradient map and the shallowest continuous horizon, namely the Campanian Outlook. The Campanian Lea Park reflection has shorter fault traces relative to the shallower PFS. These fault traces strike NW/SE & NE/SW.

15) The Campanian Outlook two way traveltime map resembles tilted fault blocks that were influenced by the Campanian Lea Park grabens (panel 13c, to the left).

16) The Campanian Lea Park reflection has shorter fault traces relative to the shallower PFS. These fault traces strike NW/SE & NE/SW. The Campanian Outlook reflection has longer strike lengths, oriented ENE/WSW. Some of the deeper faults extend to the shallower layers, as can be seen on the seismic line 'AB' in panel 12 above. The process by which some faults extend to shallower layers is under examination.

17) Geology Map.

The Demeaine marker (from well control – see Panel 3 and 6 has ~37 m of structural difference between 3-1 and 2-1-6-33W1. Well control mapping underestimates the structural complexities.

18) Geotechnical engineers have studied this area.

Rational design treatment of slides in overconsolidated clays and clay shales


"During the early part of the past century, engineers were repeatedly surprised by unforeseen movements of valley slopes on overconsolidated, flat-bedded clays and clay shales. Movements have occurred, and still persist, throughout the Cretaceous Sea area of North America. During the past 20 years the profession has been developed to the point where the element of surprise should not be an issue."
Regina Beach – a town on a landslide

The town of Regina Beach is constructed on landslides along the Last Mountain Lake valley, a glacial meltwater channel in south-central Saskatchewan, Canada. The landslides are retrogressive in nature and are seated in bentonitic clay shale of the Bearpaw Formation (piere shale)."

20) Regina Beach is subject to slides from toe slope erosion in the Qu’Appelle Valley, Saskatchewan.

The town of Regina Beach is constructed on landslides along the Last Mountain Lake valley, a glacial meltwater channel in south-central Saskatchewan, Canada. The landslides are retrogressive in nature and are seated in bentonitic clay shale of the Bearpaw Formation (piere shale)."

21) The Weyburn CO2 storage model presented below characterizes the overlying Bearpaw and Colorado (Pierre equivalents) as an aquitard. The PFS faulting suggests an aquifer, if the faults are open.

Geological Characterization of the Weyburn Field for Geological Storage of CO2: Summary of Phase I Results of the IEA GHG Weyburn CO2 Monitoring and Storage Project 1

22) Conclusions.

Same fine-grained Cretaceous sediments of the Western Interior Seaway of North America host a previously unreported polygonal fault system (PFS). At Alda, Saskatchewan, 3-D seismic data can image the PFS from ~200 m ASL to its origin at ~25 m ASL. The PFS can be geologically mapped below a depth of ~500 m ASL using welbore logs. Faulting of the Pierre Shale resulted in a graben system and a tilted fault block system at Alda. The graben system is basin Campanian and suggests local or regional extension. These grabens have affected the upper tier of the PFS. Both tiers have faults with similar displacements, but the upper tier average fault strike length is longer and the strike direction is rotated ~30° E. How the graben and tilted fault blocks and shallow bed geometries are related is still under investigation.

23) Implications and further work.

- Probably affects groundwater hydraulic conductivity.
- Faults and fractures near the ground surface or at outcrop require further examination for evidence of PFS faulting.
- Estimates of millions of faults with strike lengths of ~500m.
- Graben formation suggests extension – is this local, forebulge movement, or tectonic?
- Present day slumping from toe erosion within incised valleys could reactivate PFS fault traces.
- Surface geology work must be an integral part of this analysis.

24) References.


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Figure 1. Position of structure on slump block affects degree of damage experienced: (a) structure fully on one slump block, less susceptible to damage; (b) structure across slump between two slump blocks, very susceptible to damage.